CHAPTER III

LAUNCH VEHICLES

[redacted] The mission of a launch vehicle is to put payloads into space, either by injecting them into orbit around the earth or by sending them on lunar, solar, or interplanetary missions. The payloads launched by Air Force vehicles were developed and procured by SAMSO program offices, by the Directorate of Special Projects, or by the National Aeronautics and Space Administration (NASA). The SAMSO payloads will be discussed in Chapters IV through VII of this history, while the launch vehicles themselves will be discussed here.

[redacted] During 1980, the family of launch vehicles available to the Air Force consisted of the Scout, the Thor, the Delta, the Atlas, and the Titan III. The Scout was a solid fuel rocket consisting of four or five stages. It developed a thrust at liftoff of 130,000 pounds. The Thor and Delta were two stage, liquid fuel rockets sometimes used with clusters of three, six, or nine strap-on rocket motors. With the Rocketdyne RS-27 engine, the Thor developed 205,000 pounds of thrust; this was increased to 673,000 pounds for the Delta when the full complement of nine solid rocket motors was attached. The Atlas was a liquid fuel rocket that used two booster engines and one sustainer engine. All three engines were ignited at liftoff, but the two booster engines were jettisoned after 120 seconds of flight, leaving the remaining sustainer engine to provide the thrust necessary to achieve proper position in space. With the MA-3 engine system, the Atlas developed 388,000 pounds of thrust at liftoff. The standard Titan III core was a two stage, liquid fuel rocket with a first stage thrust of 520,000 pounds. The Titan IIIC and Titan IIID configurations included two strap-on solid rocket motors that provided

an additional 1,200,000pounds of thrust each. The Titan was far and away the most powerful of all the boosters.[1]

These boosters were used with five different upper stages. Three of the five-- the Centaur, the Transtage, and the Agena--were liquid fuel vehicles. The Centaur was the most powerful, developing about 30,000 pounds of thrust. It was used with the Atlas and was especially well suited for lunar and interplanetary missions. The Transtage and the Agena each developed about 16,000 pounds of thrust. The Transtage was used only with the Titan III, while the Agena was used with the Titan III and Atlas. The two remaining upper stages-- the Delta and the Stage Vehicle System--were solid fuel vehicles, and the amount of thrust they developed depended on the amount of propellant that was loaded into them. The Delta upper stage was used only with NASA's Delta launch vehicle, and the Stage Vehicle System was used only with the Atlas.[2]

The Air Force maintained launch facilities for these vehicles at Cape Canaveral AFS, Florida, and at Vandenberg AFB, California. Cape Canaveral was the principal launch point for what was known as the Eastern Test Range (ETR), while Vandenberg was the principal launch point for the Western Test Range (WTR). Satellites to be injected into a polar orbit were launched from Vandenberg, while those requiring an equatorial orbit were launched from the Cape.[3]

While all launches during this period were carried out by the launch vehicles described above, launches in the 1980s were to use the developing Space Transportation System.
In contrast to the existing vehicles, which were unmanned and

expendable, the Space Shuttle was to be manned and reusable. Piloted by a crew of astronauts, it would carry payloads into space and return to earth, where it would be refurbished for future missions. Together with its associated upper stages and support systems, the Space Shuttle was to form the Space Transportation System (STS).

[redacted] During the period covered in this history, SAMSO cooperated in the development of the Space Transportation System and worked to procure the expendable launch vehicles that would be needed until the STS became available. In addition, it made certain changes in the design of the expendable vehicles in order to improve their reliability and/or performance. This chapter will begin by describing the procurement, improvement, and use of expendable launch vehicles and will then move on to describe SAMSO's participation in the development of the Space Transportation System.

Scout

[redacted] The manufacturer of the Scout launch vehicle, the Vought Corporation, was under contract to NASA to carry out Scout launches from three launch sites: Vandenberg AFB, California; Wallops Island, Virginia; and San Marco Platform off the coast of Kenya. NASA supervised the launches conducted at all three sites. Scout launches at Vandenberg before 1977 had been supervised by an Air Force unit, the 6595th Space Test Group (STG), but on 19 April 1977, NASA and AFSC had signed a Memorandum of Agreement transferring technical direction of Scout launches at Vandenberg to NASA.[4]

[redacted] Early in CY 1978, NASA began urging that management responsibility for the entire Scout program be transferred to DOD in FY 1981. NASA's need for the Scout was declining, and the last launch conducted in support

of its own programs occurred on 30 October 1979. After two launches from San Marco in 1981, cooperative missions between NASA and Italy, the only scheduled users of Scout vehicles were DOD agencies. The Navy planned Scout launches through 1985 in support of its TRANSIT/NOVA program, and the Air Force ordered five Scout launch vehicles for its Instrumented Test Vehicle (ITV) program in 1982-1983. In June 1979, NASA Administrator John F. Yardley proposed to USDRE William J. Perry that Scout management responsibility be transferred to DOD in 1982 after a transition period of one year. SAMSO provided briefings on the impacts of Air Force assumption of management responsibility as well as arguments for and against it. As of the end of FY 1979, the issue was still under discussion by NASA and DOD.[5]

Thor

[redacted] Although production of the Thor SM-75 IRBM by McDonnell Douglas Astronautics Company had ceased in 1965, the Thor series of launch vehicles continued to be used for USAF and NASA space missions. At the beginning of CY 1979, thirteen Thor vehicles remained in the Air Force inventory: five LV-2Ds, two LV-2Fs, five SLV-2As, and one SLV-2H.*

* LV stands for Launch Vehicle and SLV for Standard Launch Vehicle. The LV-2D was a single-motor lower stage vehicle which was essentially the lower stage of the SM-75 IRBM without modification for a specialized payload; the LV-2F was a single motor lower stage vehicle used with a Burner II, IIA, or DMSP Block 5D upper stage (for a description of the DMSP Block 5D system, see Chapter II: "Weather, Navigation and Defense Support Systems"); the SLV-2A, also known as the Thrust-Augmented Thor (TAT), was a liquid-fueled lower stage augmented by three solid rocket motors attached to the frame, often used with an Agena or Delta upper stage; the SLV-2H, also known as the Long-Tank

[redacted] Five LV-2Fs originally had been designated to launch the DMSP Block 5D-1 satellites. The first of these satellites had been successfully placed in orbit on 11 September 1976, the second on 4 June 1977, and the third on 30 April 1978. On 6 June 1979, the fourth satellite in the series was successfully launched from Vandenberg AFB and achieved a nominal orbit. The TE-M-364-4 second stage motor and the TE-M-364-15 third stage motor used on this launch were the oldest motors of their type which had ever been launched. Although these motors were about five years old, and the previous shelf life of such motors had been placed at only two years, tests conducted by the Aerospace Corporation had indicated that they were suitable for flight. The last Block 5D-1 satellite was to be launched in 1980.[7]

[redacted] The engines of the two LV-2Fs launched in 1978 and 1979 had been replaced by larger thrust engines cannibalized from the SLV-2H and an SLV-2A. The change permitted a higher level of performance by the LV-2Fs. Two new MB-3 Block III main engines were built by the Rocketdyne Division of Rockwell International. These engines were delivered during July and August 1979.[8]

[redacted] The five SLV-2As were scheduled for DMSP Block 5D-2 missions from 1980 until the Space Shuttle would be available for placing them in orbit. During 1978 it had become apparent that problems were associated with launching the DMSP Block 5D-2 satellites on SLV-2A boosters.

Thrust-Augmented Thor, was an elongated liquid fueled lower stage with three, six, or nine attached solid motors, often used with an Agena upper stage. (Space and Missile Systems Organization: A Chronology, 1954-1976 (U), SAMSO/HO, 1976, pp. 306-307; Intvw (U), H.N. Waldron, Historian, with Capt Eleazer, SAMSO/LVMM, 8 Jun 79.)

[redacted]

Design changes had increased the projected weight of the satellites beyond the maximum throw weight of an unaided SLV-2A booster. Planners evaluated the relative merits of a transition to the more powerful Atlas launch vehicle and the addition of Castor II auxiliary motors to the SLV-2As. As CY 1979 began, SAMSO was preparing to solve the DMSP weight growth problem by adding six Castor II solid rocket motors to each SLV-2A booster. Planners soon discovered, however, that six auxiliary motors had never before been flown on the short-tank Thor (SLV-2A), only on the long-tank model (SLV-2H), and that it would cost about half a million dollars in qualification testing at Arnold Engineering Development Center (AEDC) to validate their use on the SLV-2A. As preparation for that testing began, further analysis revealed that higher performance could be obtained by using the Thiokol 37 XE solid rocket motor as the second stage, without the additional auxiliary motors. Development of the 37 XE solid rocket motor had been stopped in 1978. If the 37 XE second stage were used on the first two Block 5D-2 launches (F-6 and F-7) with the existing TE-M-364-15 third stage, the booster would meet its performance requirements. However, the following three Block 5D-2 launches (F-8, F-9, and F-10) would require the use of the 37 XF third stage with the 37 XE second stage because of the greater projected weight of these satellites. As a result of this analysis, SAMSO dropped the idea of adding the six Castor II motors and reinstated development of the 37 XE second stage.[9]

[redacted] Despite the planning outlined above, by the end of FY 1979 the

launching of DMSP Block 5D-2 satellites on Thor boosters had again come under question. Thor launches from Vandenberg AFB took place at Space Launch Complex (SLC) 10, and SAMSO recognized that the limitations of this SLC would create problems for the launches of larger, heavier Block 5D-2 spacecraft. In July, SAMSO formed a "VAFB Block 5D Requirements Working Group" from representatives of various organizations participating in the launches. The problems involved in using SLC 10 included the following: since access to the spacecraft on the launch pad would be difficult, a protective covering for the exposed spacecraft was needed, and this was unavailable at SLC 10; the mast at SLC 10 was not sturdy enough to take the additional weight of the interface equipment required for the Block 5D-2 spacecraft; a number of other modifications to the pad at SLC 10 were necessary to handle the additional weight of the Block 5D-2 spacecraft. Modifications to SLC 10 for the F-6 mission began soon after the launch of F-4; the modifications had to be accomplished without disrupting the preparations in progress for the launch of F-5. Around September, however, planners discovered that engineering predictions of the acoustic environment during the SLV-2A liftoff were inaccurate. Acoustic tests performed by RCA indicated that the noise level during the launch would be high enough to adversely affect the spacecraft. Three options seemed to be available to solve this problem: (1) redesign the spacecraft to tolerate the higher noise level and requalify it at an additional cost of about $30 million; (2) move the launch operations to SLC 2 (the NASA Delta launch pad), where the problems of the acoustic level and access to the spacecraft could be solved more easily, at an additional cost of about $6 million; (3) use the Atlas launch vehicle instead of the Thor, and option which could save about $12 million from the basic program. At the end of FY 1979, therefore, the option of switching DMSP Block 5D-2 launches from Thor to Atlas, which had been

examined and rejected in 1978 as a way of dealing with the weight growth problem*, was again under active evaluation.[10]

[redacted] Under an agreement worked out in July 1977, management of Air Force Thor launch vehicles was shared by AFSC (through SAMSO) and the Aerospace Defense Command (ADCOM). AFSC provided the boosters, integrated the payloads with the boosters, and provided logistical support; ADCOM was responsible for . launching the vehicles. The subordinate organization of ADCOM stationed at Vandenberg AFB was the 10th AERODS (Aerospace Defense Squadron), and it had as its sole function the launch support for Thor-launched DMSP satellites. Elimination of the Thor as the launch vehicle for DMSP would therefore eliminate the only operational requirement for the existence of the 10th AERODS, the only existing launch team manned entirely by Air Force military personnel. The value of retaining a cadre of trained military personnel for future space missions had been a factor in retaining the Thor as the launch vehicle for DMSP. During 1979, SAMSO and ADCOM were involved in discussions of revisions to the existing memorandum of agreement for support of DMSP, in which some responsibilities were not clearly defined. SAMSO had previously proposed absorbing the responsibilities and resources of the 10th AERODS itself.** By the end of FY 1979, however, it seemed clear that the 10th AERODS would be absorbed by SAC's 394th ICBM TMS (Test Maintenance Squadron), and SAMSO wished to wait until after the reorganization to negotiate a new memorandum of agreement with SAC.[11]

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*See Hist of SAMSO (S/RD), 1978, p. 60.
**See Ibid., p. 58.

[redacted]

Atlas

[redacted] The Atlas had originally been developed as an ICBM but had been retired from the operational inventory by the end of 1965. The retired missiles had been put to work as launch vehicles, carrying either ballistic or space payloads. By the beginning of CY 1979, Atlas was being used exclusively with space payloads. It was cheaper to refurbish a fifteen-year-old Atlas and integrate it with a space payload ($7.5 million) than to develop a new booster for the payload.[12]

[redacted] The process of refurbishing the Atlas vehicles and adapting them to the particular payloads they carried was accomplished by General Dynamics/Convair.* Convair's contract had expired in 1978, and a new contract was issued to cover FY 1979 through FY 1981. It was a Cost Plus Incentive Fee (CPIF) contract that purchased launch services as well as modification and refurbishment. The effective date of the contract was 1 October 1978, but it was not signed by the AFSC Commander, General Slay, until February 1980. Work done by Convair before that date was accomplished under extensions of the previous contract.[13]

[redacted] There were 32 Atlas vehicles in the Air Force inventory as the period began; 26 were Atlas Es and 6 were Atlas Fs. At the end of the period, 20 of the Es were still in storage at Norton AFB, and the remaining six had been shipped to the contractor for refurbishment. They were scheduled to enter service as launch vehicles in mid-1980. The Atlas F, on the other hand, was already being used to put payloads into space, and two were launched during this period.[14]

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*The process was referred to as Mod IRAN (Modify, Inspect, and Repair as Necessary).

● NOAA-A. NOAA-A was the second in a series of eight third-generation weather observation satellites built by RCA and designed and funded by NASA for the National Oceanic and Atmospheric Administration (NOAA). The first satellite in the series, TIROS-N, had been successfully launched on 13 October 1978. NOAA-A was originally scheduled for launch on Atlas 25F from Vandenberg AFB on 12 May 1979. However, a series of hardware anomalies successively delayed the launch. During acceptance tests, three of the new guidance pulse beacon decoder units, built by General Electric, experienced momentary loss of output. Although that problem was recognized and resolved early, later launch delays were caused by a malfunctioning power converter within the satellite, erroneous operation and consequent replacement of a central processing unit, and a malfunctioning inertial measurement unit. On 27 June 1979, the satellite was launched successfully on Atlas 25F and placed in a near-polar orbit at an altitude of 450 miles.[15]

● Flight P78-1. This spacecraft was procured by the Space Test Program to provide space flights for a number of experimental payloads. The primary payload, sponsored by the Defense Advanced Research Projects Agency, was a gamma spectrometer designed to measure the distributions of gamma ray sources in space. Secondary payloads included a high latitude particles experiment, a solar X-ray spectro-heliograph, an extreme ultraviolet spectrometer, a solar wind experiment, an X-ray monitor, and an aerosol monitor. The spacecraft was successfully launched on 24 February 1979 on Atlas 27F from Vandenberg AFB. The mission encountered no significant launch delays, and the spacecraft attained a good orbit.[16]

GPS STAGE VEHICLE SYSTEM

● The Global Positioning System (GPS), a space-based positioning and navigation system being developed by SAMSO, was launched on Atlas F boosters

configured with upper stage vehicles developed and built specifically for the GPS program. Fairchild Space and Electronics Company had developed the first version of the stage vehicle system, a spin-stabilized, tandem solid rocket motor which inserted a 1,720 pound GPS satellite into orbit.[17]

[redacted] It had become apparent in 1978 that the GPS satellites beginning with NAVSTAR 7 would be significantly heavier than those orbited earlier in the series. The payloads associated with NAVSTAR 7 and 9 through 11 would weigh approximately 1,900 pounds. The additional weight was added by satellite hardness improvements and a secondary payload furnished by the IONDS program.* Initial predictions had been for approximately 2,100 pound payloads associated with NAVSTAR 9 and subsequent satellites, but the requirement for a single-channel transponder, which had added the weight, was dropped. NAVSTAR 8 was to be launched without IONDS at 1739 pounds. NAVSTAR 12 was being redesigned for placement in orbit by the Space Shuttle.[18]

[redacted] Fairchild's original stage vehicle could not carry the heavier payloads, and in October 1978 SAMSO had advertised for synopses of proposals from industry for a more powerful stage vehicle system to be called SGS-II (Stage System II). SAMSO received responses from Fairchild, McDonnell Douglas, Boeing and Aerojet offering a variety of solutions to the problem, each incorporating some type of spin-stabilized solid rocket motor. On 25 January 1979, therefore, SAMSO issued a request for proposals (RFP) stipulating a firm-fixed-price (FFP) contract for two initial SGS-II vehicles. Five more vehicles would be added under a contract option if GPS was approved at a DSARC II in mid-1979. The period of performance for design, analysis, production, testing, and launch of all seven vehicles would extend from May 1979 to 31 July 1983. By the closing date

*For a discussion of IONDS, see Chapter V: Weather, Navigation, and Defense Support Systems.

for technical proposals, 13 March 1979, SAMSO had received only one proposal, from McDonnell Douglas Astronautics Company, and on 14 June SAMSO awarded the contract for the SGS II to that company. A successful preliminary design review (PDR) of the system was held on 28-30 August. By the end of FY 1979, SAMSO and the contractor were preparing for a critical design review (CDR) to be held on 30-31 October 1979.[19]

Titan III

[redacted] Three launch vehicles made up the Titan III family during this period: the IIIB, the IIIC, and the IIID. The Titan IIIB consisted of a standard core (lengthened an extra 68 inches in the vehicles launched during this period) and an Agena upper stage. The Titan IIIC consisted of a standard core, two strap-on solid rocket motors, and a Transtage as the upper stage. The IIIC was used to place satellites into very high, geosynchronous equatorial orbits. The Titan IIID consisted of a standard core and two strap-on solid rocket motors. It was used to place heavy payloads into low earth orbits. The Titan IIIE, used with a Centaur upper stage, had been employed to launch payloads into deep space for solar or interplanetary exploration, but the last Titan IIIE launch had taken place in 1977 and the vehicle had not been used since. The Titan IIIB, IIIC, and IIID were all managed by SAMSO.

[redacted] In working with the Titan III, SAMSO carried out three major tasks. First, it procured the vehicles themselves and made the necessary changes and improvements in the vehicles. Second, it procured launch services for the vehicles at Vandenberg and Cape Canaveral and arranged for the necessary modifications in the launch facilities and ground equipment at those places.

Third, it integrated payloads aboard the vehicles, sharing this task with other agencies in cases where other agencies sponsored the payloads or the upper stages. All of these activities led to the actual launching of Titan vehicles, which was supervised by the 6595th Aerospace Test Wing.[20]

TITAN VEHICLES

[redacted] The various subsystems that made up the Titan III were procured from a number of different contractors. The solid rocket motors were obtained from the Chemical Systems Division of United Technologies Corporation, the liquid rocket engines from Aerojet Liquid Rocket Company, the guidance sets for the Titan IIIC from Delco Electronics, the instrumentation systems from SCI systems, the command destruct receivers from Actron, and payload fairings for the IIIC from McDonnell Douglas. These subsystems were delivered to Martin Marietta Corporation, who manufactured the airframes (Stages I and II) for the Titan III and integrated the subsystems into them. During the period from 1 January through 30 September 1979, SAMSO accepted from Martin Marietta three completed Titan III boosters (two IIIBs, numbered B63 and B64, and one IIID, numbered D23) manufactured under contract F04701-75-C-0166. SAMSO also accepted four pairs of five-segment solid rocket motors from Chemical Systems Division manufactured under contracts F04701-77-C-0107 and -0060. Finally, Aerojet delivered four stage one and four stage two liquid rocket engines manufactured under contract F04701-76-C-0248. During the period from 1 January to 30 September, three Titans were expended as launch vehicles: one IIIB, one IIIC, and one IIID.[21] As of 30 September 1979, there were seven Titan III vehicles in storage: four IIIBs and three IIIDs. Five Titan III vehicles (two IIIBs, two IIICs, and one IIID) were at launch sites being prepared for use as launch vehicles. Three additional Titan IIICs were in package shipment at Denver before being sent to storage or to the launch site.

[redacted] In 1976, SAMSO had begun development of an improved injector for the Titan IIIC Transtage. The injector was a device that sprayed propellant into the combustion chamber of the Transtage engine, and the goal of the development program was to produce an injector that would mix fuel and oxydizer more efficiently, thereby increasing the specific impulse of the engine and enabling it to lift heavier payloads. With the improved injector, SAMSO believed that the specific impulse of the engine could be increased from 302 seconds to 310.6 seconds, which translated to an increase in payload capability of about 280 pounds.[22]

[redacted] During FY 1979, the Improved Transtage Injector Program (ITIP) was successfully completed. The contractor for this program was Aerojet Liquid Rocket Company (contract F04701-76-C-0124). During this period the contractor completed tests of the injectors and delivered the first production set of two improved injectors. The testing did not go smoothly, however. Test firings of the first deliverable ITIP engine system in April yielded highly favorable results. The injectors performed even better than expected, producing specific impulses of 310.8 seconds, a chamber life greater than 550 seconds, and stability under all tested conditions. During subsequent demonstration tests, however, evidence of contamination in the fuel channels began to appear in the form of streaks in the combustion chamber. The contamination problem had appeared during earlier phases of testing, but engineers had thought they had resolved the problem by the addition of internal screens. The first ITIP engine system was delivered at the end of June, and the second was delivered at the end of August. The engines were accepted by SAMSO only conditionally until their reliability could be proven in further demonstration testing. By the end of September, no further testing had been identified which might lessen the

risk of using the ITIP on a launch vehicle, and SAMSO was planning to fly the new hardware on the DSCS II/DSCS III launch scheduled for 1980.[23]

[redacted] In addition to developing a new Transtage Injector, SAMSO was also developing a new Titan configuration to be used during the period when expendable launch vehicles were being phased out and the Space Transportation System was being phased in. The new configuration was referred to as the Titan III 34D. It was to be used with the Inertial Upper Stage (IUS) at the Eastern Test Range and with IUS avionics at the Western Test Range. It would replace existing Titan III configurations during the period of transition to the Space Shuttle, serving as the primary launch vehicle for some payloads and as a backup to the Shuttle for other payloads. Replacement of existing Titan configurations with the 34D/IUS would offer several advantages. First, as expendable vehicles were phased out, fewer and fewer vehicles would be needed, and use of a single vehicle would reduce costs. Second, the IUS was being developed for the Space Transportation System, and use of the IUS with the 34D would allow the same upper stage to be employed with both expendable and reusable vehicles. Third, the IUS was to have a redundant, highly reliable guidance system, and use of the IUS with the 34D would therefore increase the reliability of the expendable vehicle.[24]

[redacted] A program management directive (PMD) to initiate the Titan III 34D/IUS development effort had been issued in June 1976. In June 1977, an amendment to the PMD authorized full-scale development and production, with an initial operational capability (IOC) of the system at the Eastern Test Range (ETR) in July 1980. Four contractors were involved in developing the 34D/IUS: Martin Marietta, which was to modify the booster to the new configuration; Chemical Systems Division, which was to modify the solid rocket motors; Boeing, which was to develop the upper stage; and McDonnell Douglas, which was to modify the payload fairing to be used with the upper

[redacted]

stage at the Eastern Test Range. During CY 1978, Martin Marietta and Boeing had entered full-scale development. Critical Design Reviews (CDRs) of Titan 34D structures, avionics, and ground equipment had been held in December 1978.[25]

[redacted] During 1978, the Titan 34D program had been effectively decoupled from the IUS program. This had been accomplished by eliminating IUS avionics from plans for the Titan 34D system to be used on the west coast. Titan 34Ds launched from the west coast would use a radio guidance system (RGS) instead of IUS avionics, which were more sophisticated than necessary for the simpler flight plans to be used on the west coast.[26]

[redacted] During CY 1979, configuration audits were started on the Titan 34D, effectively closing out the development phase of the system. On 4 and 5 April, a critical design review (CDR) of the radio guidance system was held and action items later successfully completed. This completed design reviews of the Titan 34D. In August and September, SAMSO started physical configuration audit (PCA) and functional configuration audit (FCA) efforts on the system, and the Air Force accepted delivery of the first vehicle.[27]

[redacted] During September 1978, SAMSO had issued a request for proposal (RFP) for a basic buy of three Titan 34D airframes with an option for two more to be exercised in May 1980. The total of five vehicles would include four to be configured with RGS for the west coast and one to be configured with IUS for the east coast. On 1 April 1979, Martin Marietta responsed to the RFP with a proposal. At the end of FY 1979, SAMSO was planning to place Martin Marietta under a fixed-price-incentive-fee (FPIF) contract in November 1979.[28]

[redacted] Testing was successfully completed on some Titan 34D subsystems.

On 25 August 1980, Chemical Systems Division of United Technologies Corporation test fired its 5½-segment solid rocket motor for the first time in its Coyote Test Facility at San Jose, California. Two of these motors would form Stage Zero for the Titan 34D. The static firing was eminently successful, generating 1.34 million pounds of maximum thrust, compared to the 1.31 million pounds predicted. A second static test firing was scheduled for 20 October 1979. Structural members of the 34D were successfully tested during 1979. The stage one fuel tank asssembly test and the outrigger tube assembly test were successfully completed, verifying the ability of the fuel tank to withstand anticipated loads in flight and the ability of the outriggger tube assembly to accomodate a 21 percent growth in loads on the 34D. Successful initial structural testing of the IUS adapter and the payload fairing was conducted at Martin Marietta's Vertical Test Fixture in Denver. Three successful payload fairing separation tests were also successfully completed at Arnold Engineering Development Center (AEDC) in Tullahoma, Tennessee by ARO, Incorporated. Both the forty-foot and the fifty-five-foot fairing lengths were successfully separated.[29]

LAUNCH SERVICES, LAUNCH FACILITIES, AND GROUND EQUIPMENT

Two contracts covering launch support for Titan III vehicles were due to expire at the end of FY 1979. Under contract F04701-77-C-0196, Chemical Systems Division of Sunnyvale, California handled storage, maintenance, and support of solid rocket motors for Titan IIICs launched from Cape Canaveral as well as Titan IIIBs and IIIDs launched from Vandenberg. Under contract F04701-77-C-0165, Aerojet Services Company performed the same services for Titan liquid rocket engines. By the end of the year, SAMSO was negotiating with both of these contractors for selected source follow-on contracts covering these efforts from 1 October 1979 through 30 September 1980. Three proposed options would extend the period of

coverage through 31 December 1982. The estimated value of launch support services for each contract through 1982 was $19.7 million.[30]

[redacted] Early in CY 1979, SAMSO completed the development and installation of an important new piece of ground equipment for Titan III launches. This equipment, referred to as the Programmable Aerospace Control Equipment (PACE) was to replace three existing pieces of computer equipment that had become obsolete and unreliable. The PACE had been developed by Martin Marietta Corporation. During CY 1978, the equipment was installed at Cape Canaveral, and installation had begun at Vandenberg. The final increments of the functional configuration audit (FCA) and the physical configuration audit (PCA) on the PACE were held at Cape Canaveral on 20-23 February 1979 and at Vandenberg on 6-7 March 1979. The first operational launch using PACE was that of a Titan IIID at Vandenberg in March 1979 (see below, LAUNCHES AND PAYLOADS), and during that event the PACE failed to perform as predicted. In September 1979, a change order to the development contract (F04701-78-C-0107) with Martin Marietta initiated an urgent development effort for PACE software to be used with the Titan 34D and radio guidance system on the west coast. The effort was to support an initial launch capability (ILC) of March 1981 and carried a target price of $1,384,000.[31]

[redacted]

[redacted] Problems causing delays in launches during this period were relatively minor. The launch of the Titan IIID during March was delayed for three days because of a problem with the Programmable Aerospace Control Equipment (PACE). This was the first time that the PACE ground support equipment had been used for an operational launch. At the direction of Lt General Richard C. Henry, SAMSO's Commander, an Independent Readiness Review Team, chaired by Col Haber of AFSCF, conducted an intensive review of the Titan IIIC to be used in the upcoming launch of a [redacted]. The failure of a Titan IIIC launch in 1978* had made it especially advisable to check exhaustively the launch-worthiness of Titan IIIC boosters carrying satellite systems with high priorities. In May, the launch was postponed because of suspected contamination in the vehicle's hydraulic tubing. The source of the contamination was identified as peeling of the metal on the inside surfaces of the tubes. SAMSO adopted the solution of inspecting and replacing suspect hydraulic system tubing on all Titan IIIs as well as inspecting all new raw stock tubing. The [redacted] Titan IIIC was successfully launched on 10 June 1979 from Cape Canaveral.[32]

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*See Hist of SAMSO, CY 1978, pp. 90-93.

Space Transportation System

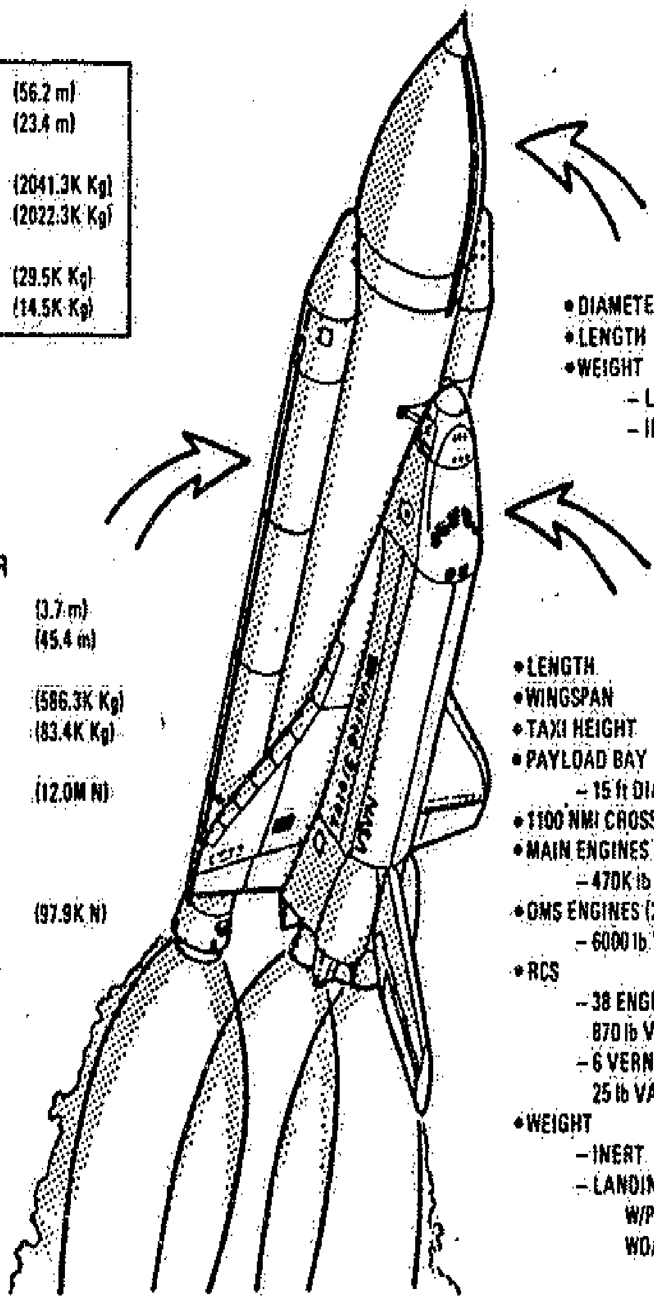
The expendable launch vehicles described in the previous sections were eventually to be replaced by the Space Transportation System (STS), which was under development during this period. The most visible element of the STS was the space shuttle orbiter, a manned, reusable launch vehicle that would carry payloads into low altitude orbit and then return to earth. The shuttle was to be complemented by upper stage vehicles that would carry payloads into high altitude orbits or into deep space for lunar, solar, and interplanetary missions. Orbiter and upper stages were to be supported by launch and landing facilities at Vandenberg AFB, California, and Kennedy Space Center, Florida, and by a Mission Control Center at Houston, Texas.[33]

The space shuttle was to have a number of advantages over the expendable launch vehicles it replaced. First, it would be able to put larger and heavier payloads into orbit. Second, it would be able to carry very bulky payloads into space one segment at a time so that they could be assembled on orbit. Third, it would be able to service and repair payloads on orbit and bring them back to earth for refurbishment there. Fourth, it would be able to act as host for observation platforms, test beds, and experimental laboratories.[34]

The STS was to be used by NASA as well as by the DOD, and most of the responsibility for developing the STS rested with NASA. NASA was to develop the space shuttle and was to construct and operate the east coast launch and landing facilities for the shuttle. However, the DOD was to construct and operate the west coast launch and landing facilities and was to develop one of the main upper stage for the STS. In addition, the DOD was to monitor the development and testing of the shuttle to insure

Space Shuttle System

•OVERALL LENGTH	184.2 ft	(56.2 m)
•HEIGHT	76.6 ft	(23.4 m)
•SYSTEM WEIGHT		
– DUE EAST	4490.8K lb	(2041.3K Kg)
– 104°	4449.0K lb	(2022.3K Kg)
•PAYLOAD WEIGHT		
– DUE EAST	65K lb	(29.5K Kg)
– 104°	32K lb	(14.5K Kg)



EXTERNAL TANK
(Tank 26 and Subsequent)

•DIAMETER	27.8 ft	(8.5 m)
•LENGTH	154.4 ft	(47.1 m)
•WEIGHT		
– LAUNCH	1649.6K lb	(748.2K Kg)
– INERT	72.2K lb	(32.7K Kg)

SOLID ROCKET BOOSTER

•DIAMETER	12.2 ft	(3.7 m)
•LENGTH	149.1 ft	(45.4 m)
•WEIGHT (EACH)		
– LAUNCH	1292.6K lb	(586.3K Kg)
– INERT	183.8K lb	(83.4K Kg)
•THRUST (EACH)		
– LAUNCH	2.7M lb	(12.0M N)
•SEPARATION MOTORS (EACH SRB)		
– 4 AFT 4 FWD		
– THRUST (EACH)	22K lb	(97.9K N)

ORBITER

•LENGTH	122.3 ft	(37.1 m)
•WINGSPAN	78.1 ft	(23.8 m)
•TAXI HEIGHT	~57 ft	(17.4 m)
•PAYLOAD BAY		
– 15 ft DIA x 60 ft LG (4.8 m DIA x 18.3 m LG)		
•1100 NMI CROSS RANGE		(2038 Km)
•MAIN ENGINES (3)		
– 470K lb VAC THRUST EA		(2090.7K N EA)
•OMS ENGINES (2)		
– 6000 lb VAC THRUST EA		(26.7K N EA)
•RCS		
– 38 ENGINES 870 lb VAC THRUST EA		(3869.8 N EA)
– 6 VERNIER 25 lb VAC THRUST EA		(111.2 N EA)
•WEIGHT		
– INERT	162.4K lb	(73.7K Kg)
– LANDING		
W/PAYLOAD ~ 205.5K lb		(93.2K Kg)
WO/PAYLOAD ~ 175.5K lb		(79.6K Kg)

that it would meet DOD needs, was to adapt its payloads for launch aboard the shuttle, and was to arrange for a mission operations system that would fulfill DOD requirements. SAMSO served as the executive agent for the DOD in all matters pertaining to the development of the STS and was involved with every element of the system--the shuttle, the upper stages, the payloads, the ground facilities, and mission operations.[35]

SPACE SHUTTLE

[redacted] The space shuttle orbiter resembled a thick-bodied, delta-winged aircraft. It would be launched with rocket engines from a vertical position and would glide to a horizontal landing. Its main engines would feed off an external fuel tank attached to its belly. A pair of solid rocket boosters attached to either side of the fuel tank would provide additional thrust. The boosters would drop off 120 seconds after launch and would be recovered and reused. The external tank would drop off later, before final orbit was achieved, but it would not be recovered because recovery and reuse of the tanks would not be economical.[36]

[redacted] The main contractor for the orbiter was Rockwell International, which was assisted by many subcontractors. During the reporting period, Rockwell was devoting most of its efforts to Orbiter 102, which would be the first orbiter to actually go into space. At the beginning of CY 1979, Orbiter 102 was being assembled at Rockwell's facility in Palmdale, California. On 8 March, it was moved to nearby Edwards AFB, and on 23-24 March, it was ferried to Kennedy Space Center on the back of a carrier aircraft (a modified Boeing 747). Once it was there, the contractor had to carry out a number of tasks in order to prepare it for launch. The most challenging of these were to finish installing thermal protective tiles on the surface of the orbiter and to install the orbiter's main engines.[37]

[redacted] The thermal protective tiles were made of silica glass fiber, and their function was to keep the orbiter from burning up as it reentered

the atmosphere during its return to earth. The orbiter was to carry 34,000 of these tiles; Rockwell had not been able to apply all of them at Palmdale, and about 10,000 still had to be applied--or reapplied--after the orbiter reached the Cape. The process went very slowly at first; only about 200 tiles were applied the first month. At this point, NASA formed a special team to oversee the tile application process, and Rockwell brought in extra workers and started working round the clock. These measures paid off; in June the tiles were being applied at a rate of 300 a week, and in July the rate went as high as 612 a week. Still, the initial difficulties with the tiles affected the schedule for the orbiter's first flight, as we will see.[38]

The main engines for the shuttle were being obtained from Rocketdyne, a division of Rockwell, and they were being subjected to a rigorous test program as the reporting period began. On 27 December 1978, an engine had failed because of a problem with its main oxidizer valve. The valve was redesigned during January 1979, and testing was resumed around the end of the month. By early April, engines equipped with the redesigned valve had completed 5,000 seconds of firing time, and there was no sign of the problem that had caused the engine failure on 27 December. On 2 July, however, there was another engine failure--this one caused by a fuel valve. The engine caught fire and damaged the test stand, and testing had to be suspended while the stand was repaired. Testing would not be resumed until late October and would not be completed until mid-March 1980.[39]

The problems with the tiles and the engines forced NASA to postpone the orbiter's first flight several times. At the beginning of the period, the flight was scheduled for September 1979; at the end, it was not expected until June 1980. Furthermore, the first four or five flights

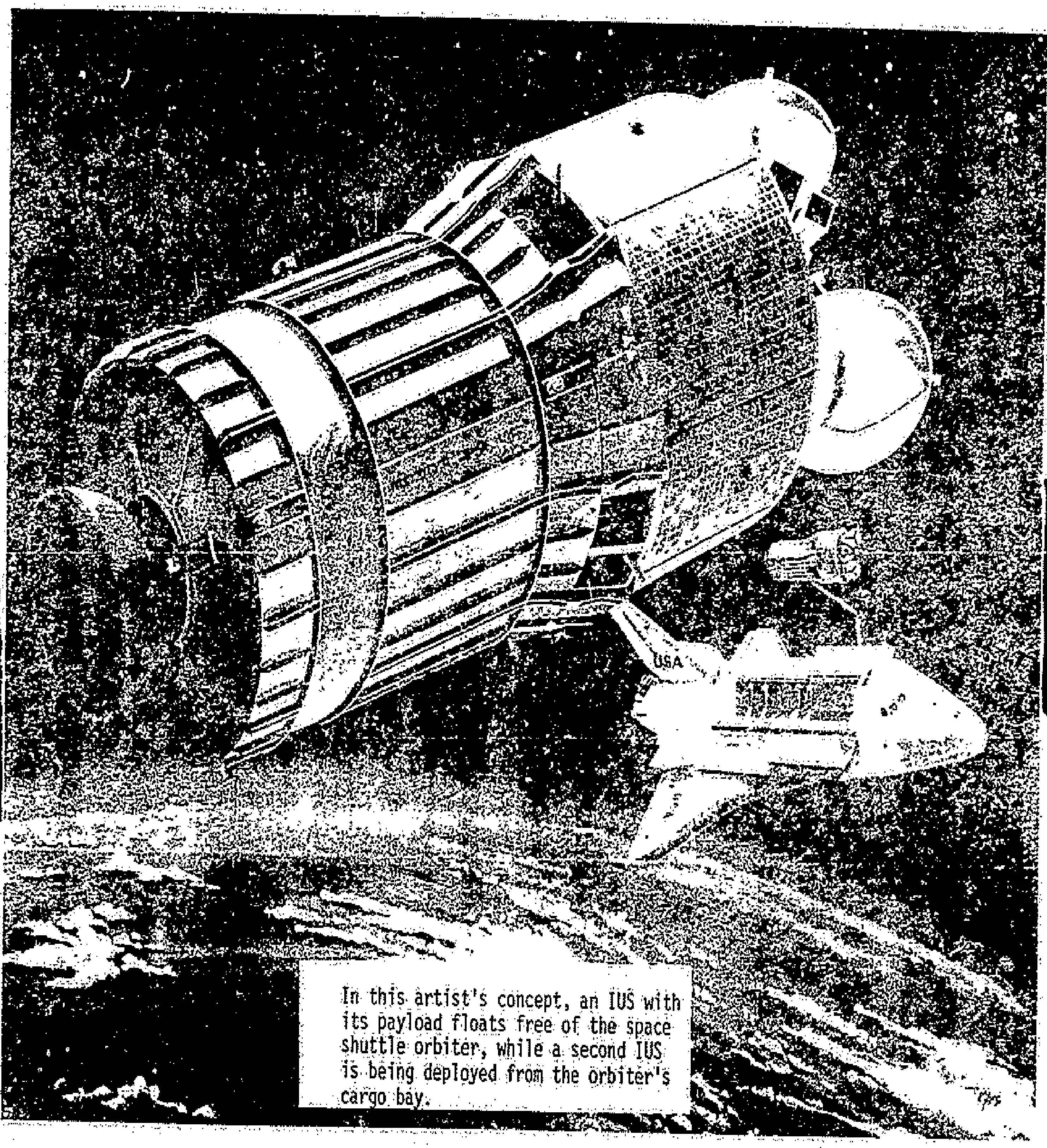
would be test flights, and the orbiter would not become operational until the fifth or sixth flight, which would not occur until September 1981 at the earliest. All this meant that some payloads previously scheduled to be launched on the shuttle would have to be delayed or launched on expendable boosters instead. SAMSO had already purchased five Titan 34D's to serve as back-ups for critical DOD missions in case the shuttle was not ready on time.. In view of the latest schedule slip, however, it appeared that SAMSO would have to review its back-up strategy and decided whether those five vehicles would be enough.[40]

INERTIAL UPPER STAGE

[redacted] In addition to the space shuttle, which would put payloads into low altitude orbits, the STS required upper stages to put payloads into high altitude orbits and carry them into space for interplanetary missions. Two upper stages were being developed at this time--a Payload Assist Module (PAM), which would be used with relatively small payloads, and an Inertial Upper Stage (IUS), which would be used with larger payloads.* The PAM was being developed under NASA auspices, but SAMSO was developing the IUS.

[redacted] The IUS was to utilize an avionics system incorporating high-reliability piece parts and redundant components, and a propulsion system employing solid rocket motors. Several different IUS configurations could be developed by using different combinations of large and small motors. One large motor and one small motor would form a two-stage configuration, two large motors would form a twin-stage configuration, and two large motors and one small motor would form a three-stage configuration. Initially, at least, the DOD would use only the two-stage vehicle; the twin-stage and the three-stage vehicles would be used by NASA.[41]

*The PAM was also referred to as the Spinning Solid Upper Stage (SSUS).



In this artist's concept, an IUS with its payload floats free of the space shuttle orbiter, while a second IUS is being deployed from the orbiter's cargo bay.

A contract for development of the IUS had been distributed to the Boeing Aerospace Company in April 1978. The contract covered the development of the standard two-stage vehicle for the DOD as well as twin-stage and three-stage vehicles for NASA. It also covered fabrication of the first nine production vehicles, along with all necessary space and ground support equipment. All this work was to be completed by December 1981.[42]

During 1979, Boeing channeled most of its energy into the development of the DOD two-stage IUS. The biggest challenges that it faced in this task involved software and propulsion. The software would be used in the IUS computer to perform guidance and navigation functions and control various vehicle operations. Late definition of requirements had put software development behind schedule, and the Critical Design Review (CDR) for the final flight software had to be postponed from January 1979 to April 1979 as a result. Following the CDR, it became apparent that the software had grown too large to fit into the computer's memory. The memory could only accept 65,500 words, and as of August, the software contained 70,415. By September, the software had been trimmed to 68,000 words, and additional steps were planned that would reduce it to 62,687 words. This would bring the software below the limit of 65,500 words, but further reductions would be necessary to provide an even greater margin.[43]

Elements of the propulsion subsystem underwent a series of tests during the reporting period. Three types of tests were performed: 1) rocket motor firings, 2) case burst tests, and 3) skirt tests. The rocket motor firings were conducted to demonstrate the soundness of the motor design. The burst tests revealed the strength of the Kevlar case that held the propellant; they were conducted by injecting water into the case to see how much pressure it could withstand before it would burst. The skirt test showed whether the Kevlar motor skirt, which formed an integral part of

the vehicle and would have to carry major loads, could in fact carry those loads.[44]

[redacted] Two rocket motor firings were conducted during the reporting period, both at the Arnold Engineering Development Center. The first firing, which involved the large motor, had originally been scheduled for October 1978. However, it had been postponed because some of the propellant in the motor had not cured properly. The soft propellant was removed and recast, and the motor was tested on 16 March 1979. It was fired for 145 seconds and generated more than 50,000 pounds of thrust. The motor's rocket nozzle was moved several times during the test to demonstrate its ability to steer the vehicle in space. The second test occurred on 25 June and utilized the small motor. The motor was fired for 95 seconds, and, again, the rocket nozzle was moved several times during the test. Both tests were considered successful.[45]

[redacted] The first case burst test had been carried out in October 1978. The case had failed the test, rupturing at a pressure far lower than predicted. Chemical Systems Division, the subcontractor for the propulsion system, attributed the failure to a defect in its manufacturing equipment. The company redesigned the equipment and strengthened the case structure as well. These measures led to improved results in six case bursts conducted between January and September 1979. As the following table shows, five of the six tests were completely successful, with the cases withstanding pressures higher than specified.[46]

Table 10

IUS Case Burst Tests, Jan - Sep 1979*

Motor Used	Date	Result	Goal
Large Motor	8 February	Burst at 1,113 psi**	1,050 psi**
" "	25 May	Burst at 1,405 psi	1,225 psi
" "	3 August	Burst at 1,366 psi	1,225 psi
Small Motor	20 January	Burst at 1,156 psi	1,225 psi
" "	4 May	Burst at 1,341 psi	1,225 psi
" "	26 July	Burst at 1,390 psi	1,225 psi

[redacted] One skirt test was carried out during the period; it was performed on a large rocket motor on 21 May. The test was completely successful, demonstrating that the motor's Kevlar skirt could handle loads of 3,000 pounds per linear inch. This constituted a record; in the past, no motor skirt had ever been required to tolerate pressures above 2,000 pounds per linear inch.[47]

[redacted] As the preceeding account indicates, almost all the tests performed on IUS motors during the reporting period turned out well. However, the optimism generated by these successes was greatly diminished by a series of problems that had surfaced by the end of the period. For one thing, it was found that cracks would develop inside the nozzle of the small rocket motor when the motor was fired. For another, about half the exit cones being procured for the motors turned out to be defective and had to be rejected. This meant that there might not be enough exit cones to support upcoming motor firings. Last and most serious, bad propellant was found in five IUS motors that were scheduled for test firings in FY 1980.

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*Source: Brfg Chart (U), "Propulsion Test Summary," no author and no date.

**Psi = pounds per square inch.

Boeing and Chemical Systems Division claimed that the motors could still be fired, but the Aerospace Corp. disagreed and felt that the motors might fail unless the propellant were replaced. If the propellant did have to be replaced, the test firings would be significantly delayed.[48]

[redacted] The difficulties that Boeing encountered in the areas of software and propulsion affected its ability to complete the overall design of the IUS. The design of the DOD two-stage vehicle was supposed to be finished early in 1979. Boeing submitted what it regarded as a final design, and it was evaluated at a Critical Design Review held in February. SAMSO felt that the design was not really finished--that issues still had to be resolved in the areas of software, rocket motors, and interface with the shuttle and the Satellite Control Facility. SAMSO asked Boeing to resolve these issues and present its solutions at a follow-on design review. As the reporting period ended, the follow-on review was scheduled for November 1979.*[49]

[redacted] Although Boeing spent most of its time designing a two-stage vehicle for the DOD, it was also designing twin-stage and three-stage vehicles for NASA. During 1978, NASA had discovered that one of its payloads would be heavier than expected, and this made it necessary to increase the performance of the three-stage vehicle. To accomplish this, a number of design changes were identified, the most important of which

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*As Boeing prepared for the follow-on review, it not only had to address the concerns expressed by SAMSO during the Critical Design Review, it had to accomplish one other task as well. During the spring, NASA announced that the yaw motions of the orbiter during launch would be greater than expected. This would put an increased strain on the IUS and the Aerospace Support Equipment that would hold it in place inside the orbiter. To deal with the problem, Boeing had to make design changes that would strengthen the Support Equipment and dampen the side-to-side motions of the IUS. (Brfg Charts (U), SAMSO/LVI, "Program Management Review: Inertial Upper Stage," 7 Jun and 13 Jul 79; Intvw (U), T.C. Hanley, Historian, with Capt William Lewis, SD/YVI, 21 Jul 80.)

involved the addition of an extendible exit cone (EEC) to the small rocket motor. The EEC would be used to lengthen the rocket nozzle of the small motor and allow greater expansion of the exhaust gas. It would improve the performance of the two-stage IUS as well as the three-stage IUS, and for this reason it would benefit the DOD as well as NASA.* The EEC and the other performance-improvement features were added to the IUS contract through a change order issued on 6 March 1979. The total value of the change order was $8,945,000. The DOD was to pay $2,891,000, which was roughly half the cost of the EEC. NASA was to pay the rest.[50]

Boeing was originally supposed to complete the preliminary design of the NASA IUS vehicles in early 1979, and the Preliminary Design Review was scheduled for March. However, the review was postponed to August, and when it finally occurred, Boeing's preliminary design was rejected as incomplete. Boeing was told to come back with an adequate preliminary design by the end of the calendar year. As a result, Boeing found itself behind schedule in its work for NASA as well as its work for the DOD.[51]

These schedule slips were accompanied by a cost overrun. The possibility of an overrun was foreseen early in the year, and by spring the possibility had become a certainty. The IUS Program Office asked the contractor to work out an estimate of exactly how much it would cost and how long it would take to complete the existing development program. After analyzing the situation, Boeing informed the Program Office that when the development program was completed, the cost overrun would amount to $63.6 million; the government's share of this would be 90 percent, or $57.2 million. Boeing also estimated that the IUS would attain an initial launch capability

*For information on performance problems affecting the two-stage IUS, see Hist of SAMSO (S/RD), 1978, p. 101. Incorporation of the extendible exit cone solved these problems.

in August 1980. The Program Office felt that both the cost and schedule estimates were too optimistic. They expected an overrun of $84.1 million--the government's share would be $75.7 million--and they believed the IUS would not attain an initial launch capability until July 1981.[52]

[redacted] Regardless of the precise extent of the cost overrun and schedule slip, it was obvious that they would both be severe. In order to deal with the situation, SAMSO began negotiating with Boeing in an effort to restructure the IUS contract. SAMSO hoped to work out new delivery dates for the IUS vehicles purchased through the contract and to put a cap on the contract, so as to limit the government's liability and protect it from the impact of further cost growth. The negotiations got under way in August, and it quickly became apparent that the two sides were far apart. Negotiations were still going on as the reporting period ended, and it was clear that they would be long and difficult.[53]

PAYLOAD INTEGRATION

[redacted] As the orbiter and the IUS were being developed, SAMSO was arranging for the integration of DOD payloads into those vehicles. SAMSO had hired Martin Marietta to integrate payloads into the orbiter and Boeing to integrate them into the IUS. Each company had a basic contract under which it developed the procedures and tools necessary for integration. Annexes were later added to the contracts, authorizing the companies to apply the procedures and tools to the integration of specific payloads. During the reporting period, Martin was working on the integration of payloads for the Defense Satellite Communications System (DSCS), the Defense Support Program (DSP), and the Satellite Data System (SDS), as well as for Space Test Program Flight P80-1. Boeing, for its part, was working on the integration of payloads for DSCS and DSP, and also on the integration of two NASA payloads--the Tracking and Data Relay Satellite (TDRS) and the Galileo

orbiter/probe. NASA supplied the funding for the TDRS and Galileo work, and SAMSO channeled the money to Boeing through the IUS integration contract.[54]

[redacted] Other payloads were scheduled for integration into the shuttle and the IUS later on, and one of these was the Global Positioning System (GPS) Phase III satellite. During 1978, however, SAMSO had come to the conclusion that it would be more cost effective to launch GPS satellites on smaller upper stages specifically tailored to their requirements. In January 1979, SAMSO wrote to HQ AFSC, asking permission to launch the GPS satellites on a tailored upper stage. HQ AFSC thought the idea was attractive, and it asked SAMSO to prepare a briefing, outlining the advantages of a tailored upper stage and the cost impact of using it. The briefing was presented to the Vice Commander of AFSC on 6 June. It indicated that the IUS was designed to deliver heavy, complex spacecraft to high altitude orbits, whereas the GPS satellites were relatively small and simple and were going into medium altitude orbits. They could therefore utilize a smaller, lighter, cheaper upper stage, such as the Payload Assist Module (PAM) being developed for NASA by McDonnell Douglas.* SAMSO estimated that the DOD would realize significant cost savings by launching the GPS satellites with the PAM instead of the IUS, and it recommended that the change be made. HQ AFSC approved this recommendation and sent it forward

*McDonnell Douglas was building two versions of this vehicle--the PAM-A and the PAM-D. It was the PAM-D that SAMSO wanted to use with the GPS satellites. PAM-D would be 48 inches in diameter and 76 inches long, and would weigh about 4,500 pounds. In contrast, the two-stage IUS would be 15 feet long and 10 feet in diameter and would weigh almost 32,000 pounds. (Robert M. Powers, The World's First Spaceship: Shuttle (Harrisburg, PA.: Stackpole Books, 1979), pp. 137-138; Ltr (U), R.L. Johnson, President, McDonnell Douglas Astronautics Company, to LtGen R.C. Henry, SAMSO/CC, subj: "MDAC PAM-D System for GPS Phase III Program," 2 Jul 79 (Doc III-46); Fact Sheet (U), SAMSO/OI, "The Inertial Upper Stage," May 78. [redacted]

to HQ USAF. As the reporting period ended, HQ USAF had not yet decided whether to accept the recommendation.[55]

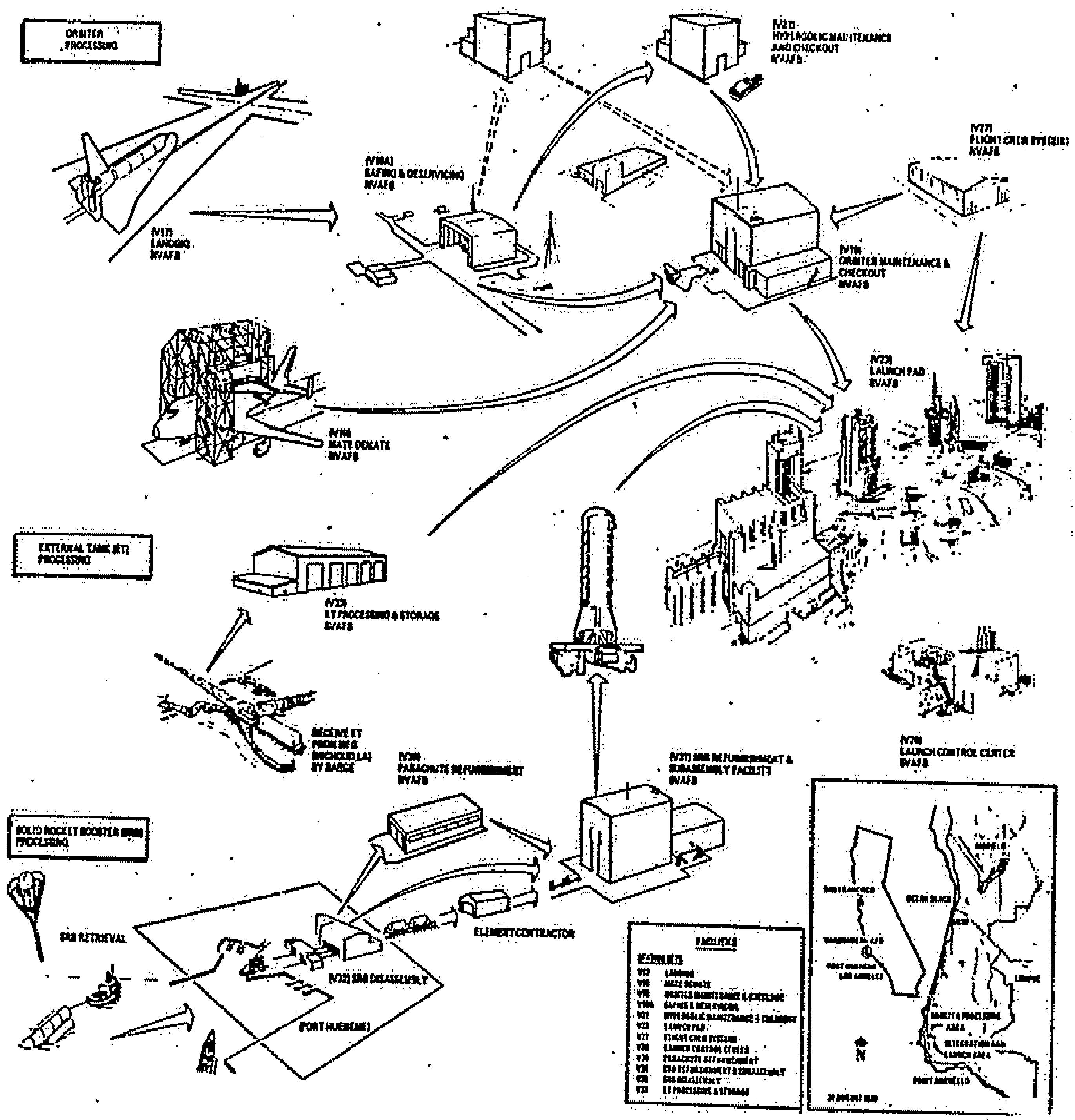
GROUND FACILITIES

[redacted] Vandenberg AFB. The biggest and most expensive task that SAMSO had to perform in helping to develop the Space Transportation System was the construction of ground facilities for the STS at Vandenberg AFB, California. The facilities at Vandenberg were to be used in processing the space shuttle orbiter, its solid rocket boosters, its external fuel tank, and its payloads. The processing of the orbiter would begin when it landed at Vandenberg after completing a mission in space. Once back on the ground, it would undergo safing and deservicing and then maintenance and checkout in preparation for its next flight. The solid rocket boosters would have dropped off the orbiter during flight and parachuted into the ocean. They would be recovered, brought to shore, taken apart, and shipped to Utah for reloading of propellant. Once reloaded, they would be returned to Vandenberg and reassembled. The external fuel tank would also have dropped off the orbiter during flight, but it would not be recovered; rather, new tanks would be procured for every flight. They would be manufactured in Michoud, Louisiana, sent by barge via the Panama Canal to Vandenberg, and processed and stored until needed. When time came for the shuttle to perform another mission, the orbiter, the boosters, and the external tank would be brought to the launch pad, erected in a vertical position, and joined together. The payload or payloads would then be installed in the orbiter's cargo bay, and the shuttle would be launched into space.[56]

[redacted] As the reporting period began, the schedule for acquisition of the space shuttle facilities at Vandenberg was in a state of flux. HQ USAF had directed AFSC and SAMSO to acquire the facilities through a four-year construction program and to have Vandenberg ready for initial

VANDENBERG SHUTTLE OPERATIONS

ONLINE AND OFFLINE FLOWS FOR LAUNCH



operations in mid-1983. At the same time, however, NASA had informed SAMSO that it intended to add strap-on motors to the space shuttle's solid rocket boosters in order to augment the thrust of the shuttle. SAMSO would have to modify the configuration of the launch pad to accomodate the strap-on motors, and it was impossible to do this within the schedule laid out by HQ USAF. In January 1979, therefore, SAMSO asked HQ USAF to stretch the construction program from four years to five and change the target date for the initial launch capability from mid-1983 to March 1984. In February, HQ USAF approved the five-year construction program, but it only slipped the target date to December 1983--not March 1984.* SAMSO doubted that it could have the pad ready by December 1983, but it devised a high-risk, success-oriented construction schedule in an attempt to meet the deadline.[57]

[redacted] The projects making up the five-year construction program at Vandenberg are shown in the accompanying table. Responsibility for designing the various projects was divided among the Air Force, the Navy, and the Army Corps of Engineers. The Air Force and the Navy hired private architectural-engineering firms to work up designs for their projects, while the Corps of Engineers farmed out some of the design work to private firms and did the rest itself. Actual construction activity that followed the design would be contracted for by the Corps of Engineers or the Naval Facilities Command. Air Force Systems Command was to control funds, monitor construction in progress, and approve major configuration changes.[58]

*The rationale for this action was the following. Congress felt that procurement of space shuttle orbiters should be tied to the availability of launch facilities for them. If the operational date for Vandenberg moved from 1983 to 1984, Congress might respond by postponing the procurement of additional orbiters. When HQ USAF told AFSC and SAMSO to have Vandenberg ready for operation by the end of 1983, it was attempting to guard against such a possibility. (Notes (U), by T.C. Hanley, Historian, on Pre-Program Assessment Review for the Space Transportation System, given by Col Joseph Mirth, SAMSO/LV, 13 Mar 79; Intvw (U), T.C. Hanley, Historian, with LtCol Richard S. Merdian, SD/YVV, 23 Jul 80.)

Table 11

STS Facilities at Vandenberg AFB*

Year	Project
FY 1979	Launch Pad, Phase I (Site Preparation) Launch Pad, Phase II (Construction) Launch Pad, Phase III (Construction) Launch Control Center
FY 1980	Titan III Resiting Orbiter Maintenance and Checkout Facility Hypergolic Maintenance and Checkout Facility, Phase I Utilities
FY 1981	Airfield and Mate/Demate Facility Solid Rocket Booster Processing (Vandenberg) Solid Rocket Booster Disassembly (Port Hueneme) External Tank Processing Transportation Logistics Integrated Operations Support Center and Shuttle Management and Engineering Facility
FY 1982	Boathouse Dock and Tow Route Breakwater Addition Parachute Refurbishment Flight Crew System
FY 1983	Safing and Deservicing Hypergolic Maintenance and Checkout Facility, Phase II

The main item in the FY 1979 construction package was the launch pad. The pad that the shuttle would use was Space Launch Complex 6 (SLC 6), which had been built in the late 1960's as the launch site for the Manned Orbiting Laboratory. SAMSO would save about $30 million by adapting SLC 6 to the shuttle instead of building a new launch pad. The adaptation process would be carried out in three phases, with site preparation being accomplished in Phase I and construction in Phases II and III. On 19 January 1979, the Corps of Engineers awarded a $3.8 million contract for Phase I to Morrison-Knudsen, Inc., of Boise, Idaho. The contractor's task was to do some

*For detailed descriptions of these projects and the work done on each one during the reporting period, see Appendix No. 8.

excavation work and to demolish certain existing structures that would have to be replaced. Ground breaking occurred on 24 January, and Phase I was 97 percent complete by the end of the reporting period.[59]

[redacted] As indicated earlier, NASA had decided to add strap-on solid rocket motors to the shuttle in order to augment its performance, and SAMSO had to modify the launch pad to adapt it to those motors. Some of the modifications had to be implemented as the pad was being built; others could be carried out later on. In February 1979, HQ USAF directed that the first set of modifications be made in FY 1980. The second set would be made in FY 1983, provided it was still needed. The total cost of accomodating thrust augmentation would be $63.8 million; $32.6 million of this amount would go for construction, with $13.5 million being spent in FY 1980 and $19.1 million in FY 1983.[60]

[redacted] Along with the launch pad, the FY 1979 construction package also included the Launch Control Center. Design of the Center was under way as the period began and was 90 percent complete by mid-April. At this point, however, NASA indicated that it would need space in the facility for analyzing and solving problems that might arise during countdown and launch. This was a new requirement, and it was necessary to revise the design of the Launch Control Center to accomodate it. Work on the revised design started in July and was 40 percent complete by the end of the reporting period. The need to revise the design forced SAMSO to postpone the start of construction from August 1979 to March 1980.[61]

[redacted] The Launch Control Center was the object of a so-called vibro-acoustic study which was under way during this period. The purpose of the study was to determine whether the vibration and the noise generated by the shuttle's three liquid rocket engines and two solid rocket boosters would create problems for the Launch Control Center or the computer equipment

[redacted]

it would contain. The study also looked at the effect that the vibration and noise would have on the Payload Preparation Room and the payloads that would be processed in it. Martin Marietta Corporation carried out the study with the assistance of the Aerospace Corporation and several subcontractors. Martin started work around the beginning of the reporting period and was scheduled to finish up in January 1980.[62]

[redacted] The construction packages for FY 1980 through FY 1983 included 17 projects, and most of these projects were being designed during the reporting period. (See Appendix No. 8.) In general, the design work proceeded smoothly, but in some cases it encountered delays, generally caused by changes in requirements. Facilities affected by such problems included the Orbiter Maintenance and Checkout Facility, the Solid Rocket Booster Processing Facility, and the Solid Rocket Booster Disassembly Facility.

[redacted] The Orbiter Maintenance and Checkout Facility would be used to process the orbiter, load certain types of payloads into it before it was launched,* and remove payloads from it after it landed. During the spring of 1979, various satellite programs introduced new requirements relative to the support of their payloads in the facility. It was necessary to change the design of the facility to accommodate these requirements, and design work fell behind schedule. To keep the design slippage from holding up construction, SAMSO decided to split the project into two packages. Package I would include preparation of the foundation, and Package II would include everything else. Construction could begin once the design for Package I was finished, which would occur early in FY 1980.[63]

[redacted] The Solid Rocket Booster Processing Facility would be used to prepare and integrate the major assemblies of the solid rocket boosters

*Most payloads would be loaded into the orbiter while it was at the launch pad. However, those that had to be inserted in a horizontal position would be loaded while the orbiter was in the Maintenance and Checkout Facility.

prior to launch. From the Processing Facility, these assemblies would be taken to the launch pad, where they would be stacked up and mated with the external fuel tank and the orbiter. Following launch, the boosters would drop off the orbiter and fall into the ocean. They would then be recovered and taken to the Solid Rocket Booster Disassembly Facility, in Port Hueneme, where they would be cleaned and taken apart. From the Disassembly Facility, certain parts of the boosters would be shipped directly back to the Processing Facility, while other parts would be shipped first to the contractor--to be loaded with propellant--and then to the Processing Facility. At the Processing Facility, the whole complex cycle would start over again.[64]

[redacted] The Processing Facility had originally been conceived as a relatively simple set up that would concentrate on the final step in the preparation and integration of the booster assemblies--that is, the build-up of the assemblies themselves. As time went by, however, the operations to be carried on in the facility had been expanded to include the build-up of components and subassemblies as well as assemblies. As a result, the facility had to become more complex and take on more of a manufacturing role. On 18 May, the design of the facility was placed on hold so that the specifications could be revised to incorporate these new requirements. The revised specifications had been completed by the end of the fiscal year, and design work was expected to resume early in FY 1980.[65]

[redacted] Two important changes were made in the configuration of the Disassembly Facility during the reporting period. First, SAMSO decided to set up two lines for cleaning and disassembling the boosters instead of just one. This would allow operations to continue even if one line should break down. Second, SAMSO was directed to lengthen the wharf that would serve the facility and improve it by adding a sewage system and raceways for utilities. These

modifications to the wharf were made at the request of the Navy. Design work on the facility was suspended in January, to allow these changes to be defined, and was resumed in July.[66]

[redacted] SAMSO was not only responsible for providing facilities for the STS; it was also responsible for obtaining the equipment that would be used in those facilities. One of the most important sets of equipment to be procured was the Vandenberg Launch Processing System (VLPS). The VLPS would be used in checking out and launching the space shuttle and in controlling and monitoring the operation of the ground systems. It would consist of three subsystems: a Central Data Subsystem (CDS), which would include a large-scale computer; a Control, Checkout, and Monitor Subsystem (CCMS), which include mini-computers, consoles, and display devices; and a Record/Playback Subsystem (RPS), which would include tape recorders. SAMSO was procuring and installing the RPS itself, but it was delegating procurement and installation of the CDS and the CCMS to NASA, since those two subsystems were identical to subsystems that NASA was using at Cape Canaveral. SAMSO would reimburse NASA for the cost of the equipment and the expense of installation.[67]

[redacted] The VLPS was to be installed in two places--the Launch Control Center in South Vandenberg and Building 8510 in North Vandenberg. Each building would get a CDS, a CCMS, and an RPS. The equipment in Building 8510 would interface with the Safing and Deservicing Facility, the Orbiter Maintenance and Checkout Facility, and the Hypergolic Maintenance and Checkout Facility. The equipment in the Launch Control Center would interface with the Solid Rocket Booster Processing Facility, the External Tank Processing Facility, and the launch pad.[68]

[redacted] Procurement of the VLPS had started in October 1977, and installation had begun in August 1978. The first building to receive the

equipment was Building 8510, and the first subsystems to be installed were the CDS and the CCMS. Both subsystems were installed in two increments. The first increment of the CDS went into 8510 between August and November 1978; installation of the second increment was carried out between May and November 1979. The first increment of the CCMS was installed between November 1978 and April 1979; installation of the second increment started in September 1979 and was scheduled for completion in February 1980.[69]

In order for the acquisition of STS facilities to proceed, SAMSO had to assess the impact that construction and operation of the facilities would have on the environment. SAMSO had finished an environmental impact statement in 1977, but as the reporting period began, it was still investigating certain issues that had not been covered sufficiently in the original statement. These related to the effect of sonic booms from the space shuttle on the mammals and birds of the Channel Islands, the effect of harbor construction on the marine biology of the Point Arguello area,* and the effect that construction and operation of space shuttle facilities would have on air quality at Vandenberg. The first of these three studies was finished during the reporting period.[70]

The study was conducted by San Diego State University and the Hubbs/Sea World Research Institute. The study noted that a few space shuttle flights would pass over the Channel Islands during launch, and all such flights would pass over the islands during landing. These flights would generate sonic booms, with the booms during launch being particularly severe. The Channel Islands, which were off the California coast to the south of Vandenberg, supported some of the most important seabird colonies and most diverse rookeries of seals and sea lions in the United States.

*SAMSO planned to build a shallow harbor at Point Arguello to receive the shuttle's external fuel tanks, which would be brought in by barge from Michoud, Louisiana.

The study concluded that the sonic booms would startle these birds and mammals severely, disrupting their social structure and their reproductive behaviour and possibly causing them to panic and to damage their eggs, nests, and young as they ran or flew away. The sonic booms might also cause temporary or permanent loss of hearing and might produce stress reactions which could affect endocrine systems or reproductive physiology. Finally, the overpressures produced by sonic booms might cause the collapse of fragile cliff areas used as nesting sites by marine birds and the collapse of burrows used by some birds, mammals, and reptiles. The study indicated that the available data did not allow researchers to predict exactly how serious these problems would be. Further research would diminish the uncertainty, but definite answers would not be available until space shuttle flights actually occurred.[71]

In addition to studying the environmental impact of the shuttle, SAMSO had to take steps to mitigate that impact where necessary. One place where mitigation was needed was Point Arguello, where SAMSO planned to build a harbor for the barges that would bring the shuttle's external fuel tanks to Vandenberg. An unused Coast Guard station was located at Point Arguello, and part of the station--specifically, a boathouse and pier--would have to be demolished to allow the harbor to be built. On 25 March, representatives from SAMSO and various civilian agencies met to discuss how the environmental impact of this demolition could be mitigated. SAMSO agreed to prepare a historical report on the boathouse and take photographs and make engineering and architectural drawings of it. The State Historical Preservation Office agreed that preparation of this archival material would constitute a satisfactory mitigation measure. However, SAMSO would also have to draw up a case study describing other mitigation actions that the Air Force had considered, and the Advisory

Council on Historic Preservation would have to review the case study and the archival material and decide whether the proposed solution was adequate. As the reporting period ended, SAMSO had Tetra Tech, Inc., working on the case study, which was supposed to be completed in 1980.[72]

● Kennedy Space Center. The west coast launch and landing site at Vandenberg was to be complemented by an east coast site at Kennedy Space Center (KSC). NASA was responsible for developing most of the facilities at KSC, but SAMSO was to develop those facilities that would be used to assemble and check out the Inertial Upper Stage (IUS) and mate the IUS with its payloads. The first of these operations was to be carried out in the Solid Motor Assembly Building (SMAB). The SMAB had previously been used to assemble the solid rocket motors used by the Titan IIIC and IIIE, and it had to be modified so it could support assembly and checkout of the IUS. The modifications were being accomplished by the Army Corps of Engineers. SAMSO had originally planned to have the modifications accomplished in two phases, but this idea was dropped and they were all done at the same time. A contract for the modifications was awarded in February 1979, and construction was 60 percent complete at the end of the reporting period.*[73]

● While the SMAB had been chosen as the location for assembly and checkout of the IUS, the Air Force was still debating the best location for mating the IUS with its payloads. Two different approaches could be used in carrying out this operation. In the first of these, called the factory-to-pad approach, the IUS would be mated to its payloads on the

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*This work was done as part of a package that also included modifications to the Mobile Service Tower at Launch Complex 40. The Mobile Service Tower would be used to support launches of the Titan 34D--a new Titan configuration that was being developed at this time. For information on the 34D and the facility modifications being carried out for it, see the Titan section of this chapter.

launch pad itself. In the second approach, the IUS would be mated to the payloads in some off-line facility and brought to the launch pad from there. The Air Force had employed the factory-to-pad approach with expendable launch vehicles at Vandenberg, and HQ USAF had directed that it be used with the IUS at KSC. SAMSO, however, felt that the IUS should be mated to its payloads in an off-line facility and that the best off-line facility for the purpose was the SMAB.[74]

[redacted] In March 1979, a SAMSO representative briefed HQ AFSC and HQ USAF on the disadvantages of the factory-to-pad approach. The briefing indicated that integration on the pad would create operational and safety problems and would make it more difficult to maintain security and keep payloads free of contamination. In addition, it would tie up the orbiter and the launch pad for lengthy periods and thereby reduce the launch rate. Finally, it would make it more complicated and expensive to verify the functional and mechanical interfaces between payloads and the STS. In light of these considerations, the briefing recommended that HQ USAF discard the factory-to-pad approach and have the IUS mated to its payloads in the SMAB.[75]

[redacted] HQ USAF accepted this recommendation and directed that an off-line payload processing capability be developed. However, there was still some question about when the project would be funded. SAMSO wanted it funded in FY 1981; HQ USAF preferred to wait until FY 1982. In August and again in September, SAMSO personnel traveled to Washington and briefed HQ USAF on the need for FY 1981 funding. A decision on the matter was expected early in FY 1980.[76]

MISSION OPERATIONS

[redacted] Mission operations embraced those activities required to prepare for and execute an STS mission from lift-off through landing. They included

mission planning and mission readiness, which took place prior to flight, and mission control, which took place during flight. All three activities were to be carried out with the aid of a mission operations system, which would include the hardware, software, and facilities required to plan, conduct, and support mission operations.[77]

[redacted] Initially, the Air Force would use NASA's Johnson Space Center in Houston to conduct mission planning, mission readiness, and mission control activities. However, use of Johnson Space Center (JSC) presented security problems. Many missions that the shuttle would perform for the DOD would be classified, and JSC had never been used for such missions and was not equipped to protect the classified information that would have to be handled during them. In order to equip the NASA facility to handle this information, buildings would have to be modified, secure communications would have to be installed, and computing capability would have to be added.[78]

[redacted] The first step in getting ready to modify JSC was to develop requirements that would indicate exactly what modifications had to be carried out. NASA and SAMSO finished this task in the spring of 1979. NASA then began designing the modifications, with SAMSO reimbursing it for its efforts. The modifications were to affect several buildings at JSC, but most of them would be carried out in Building 30, which housed the Mission Control Center, and most of the remainder would be carried out in Building 5, which contained the Shuttle Mission Simulator. A Preliminary Design Review (PDR) for Building 30 was held in September 1979, and a PDR for Building 5 was scheduled for the spring of 1980. Construction was scheduled to start in March 1980 and finish in March 1981, so that JSC would be capable of supporting classified operations by December 1981.[79]

[redacted] Modification of JSC was going to be expensive. In late 1978, SAMSO had estimated that it would need $10 million in FY 1980 for construction alone. By mid-1979, the estimate had risen to $12.4 million. More refined estimating techniques brought the figure down to $8.9 million, and Congress appropriated this amount in the FY 1980 budget. However, in addition to money for construction, SAMSO also needed funds for additional computer hardware and modification of existing hardware, for security engineering, and for software security validation. When the cost of these items was added to the cost of construction, the total amount needed to equip JSC to support classified missions was $74 million. HQ USAF felt that this amount was too high, and in February 1979 it directed AFSC to reduce the cost to $60 million. As we will see later in this section, even greater reductions were directed later in the year.[80]

[redacted] Although the DOD was going to employ NASA's facilities at JSC in the early years of the shuttle era, it hoped eventually to acquire separate facilities of its own. This aspiration was not necessarily supported by the rest of the executive branch, however, and early in the reporting period, the Office of Management and Budget (OMB) initiated a study to determine whether separate facilities were really needed. The study was carried out for OMB by the Air Force Satellite Control Facility, aided by NASA and by SAMSO's STS Program Office. It looked at three basic ways of meeting DOD's mission control requirements: 1) continued use of JSC; 2) use of a separate DOD facility located at JSC; and 3) use of a separate DOD facility located elsewhere. Option 3 had a number of variations, involving colocation or integration of the shuttle mission control facility with some other DOD facility--for example, the Satellite Test Center in Sunnyvale or the Satellite Operations Center, which was a proposed

back-up to the Satellite Test Center.* The study concluded that the most attractive alternative, from an operational and cost standpoint, was a separate DOD facility colocated or integrated with the Satellite Operations Center.[81]

[redacted] The idea of colocating a DOD shuttle facility with the Satellite Operations Center was taken up by Dr. Hans Mark, the Under Secretary of the Air Force. In a letter to General Lew Allen, Air Force Chief of Staff, Dr. Mark indicated that a number of Air Force programs needed facilities for the control of space assets. He expressed the opinion that most of these requirements could be met with some type of consolidated facility that would be more economical to develop and operate than several separate facilities. Dr. Mark asked HQ USAF to develop a concept of operations for such a consolidated facility. He indicated that the facility should combine the functions of a Shuttle Operations and Planning Center, a Satellite Operations Center, and a Master Control Center for the Global Positioning System (GPS) program.[82]

[redacted] The concept of operations that Dr. Mark asked for was prepared by a special working group within Air Force headquarters and was finished on 12 July. It called for the development of a Consolidated Space Operations Center (CSOC) that would function as a Shuttle Operations and Planning Center and as a Satellite Operations Center. Contrary to the original intention, the facility would not function as a Master Control Center for GPS. The Master Control Center was dropped from the CSOC baseline because

*The Satellite Test Center (STC) was at the heart of a worldwide network of tracking stations used to monitor and control DOD satellites. The Satellite Operations Center would be built to complement the STC and take its place in case the STC were put out of action by natural disaster or enemy attack. (Rpt (C), AFSCF, "USAF Site Survey 78-21, Vol I: Initial Site Survey Summary (U)," Feb 79.)

of fiscal limitations and uncertainty over the future course of the GPS program. The possibility remained, however, that it might be reintroduced into the CSOC later on.[83]

[redacted] The OMB study and the concept of operations indicated what sort of facility the DOD would develop and what role it would play. The question remained, however, as to where the facility would be located. In 1978 and early 1979, the Air Force Satellite Control Facility had surveyed 12 different sites as possible locations for its Satellite Operations Center. These sites were also the ones initially considered for CSOC. In June 1979, HQ AFSC narrowed the list to four sites: Kirtland AFB, New Mexico; Luke AFB, Arizona; Peterson AFB, Colorado; and Malmstrom AFB, Montana. Luke was withdrawn from the list after the Tactical Air Command indicated that the presence of CSOC would interfere with its activities at that base. In September HQ USAF sent a survey team to the remaining three sites, and final site selection was expected in FY 1980.[84]

[redacted] With the DOD and the Air Force committing themselves ever more firmly to a separate DOD facility for control of shuttle missions, it was becoming clear that the DOD's use of JSC would be strictly temporary. Dr. Hans Mark emphasized this point in his aforementioned letter to General Lew Allen on 18 June, and he added that the DOD should scale down its investment in JSC to avoid being locked into protracted use of that facility. On 31 July, HQ USAF asked AFSC to lay out the strategy for transitioning from JSC to a DOD facility and to include options for scaling down the DOD's investment at JSC. SAMSO formulated the strategy and the options and briefed them to Dr. Mark on 30 August. Dr. Mark selected an option which reduced the DOD's investment in JSC from $60 million--the previous target--to $44.2 million. This was to be done by deleting JSC's capability to support two classified operations at once, by deleting software security

validation, and by deleting one of four Shuttle Data Processing Computers. AFSC indicated that it would make a concerted effort to meet the new cost goal.[85]